CH_2 Setting a new world standard in green building design

Design snap shot 05: Energy Systems

Summary

Introduction

This snap shot discusses the energy saving initiatives undertaken at Council House 2 (CH_2). It outlines the reasons why the energy saving initiatives were integrated into the development, what the costs and benefits are, and the final outcome.

Drivers and objectives

The main driver of CH_2's energy efficiency measures is to reduce the greenhouse impact of the building. This is a part of Council policy, as outlined in Council's Cities for Climate Protection™ commitments. Specific targets are set out under the Zero Net Emissions by 2020 Strategy to guide corporate change:

- 5% Increase in the use of renewable energy by 2005 and 10% increase by 2010;
- 30% reduction in Council's emissions (on 1996 levels) by 2010;
- Zero net emissions by 2020.

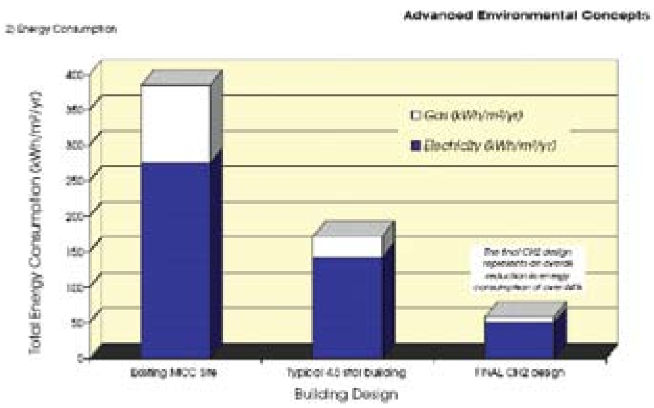

Figure 1. Predicted energy savings in kwh/m2/yr (AEC)

Costs and benefits

Costs

The costly items relating to energy have been the phase change material and the chilled ceiling and beam systems. The shower towers and the turbines are costly for their economic return, but their demonstration benefits are of high value. The good design, lighting systems and night purge do not have a cost premium (i.e. they cost the same as regular features).

Benefits

- Saving of $36/m2/yr or $270,000 per year on energy costs.
- The Australian Greenhouse Building Rating Scheme indicates CH_2 emissions will be 60 per cent less than a top-rating 5-star building.
- Liquid Crystalline Display (LCD) computer monitors are expected to consume 77% less energy than the current tube monitors.
- T5 light fittings will consume 65% less energy than Council House 1.
- 48m² of solar panels will provide about 60% of the hot water supply.
- 26m² of photovoltaic cells will generate about 3.5kW of electricity from the sun.

Design outcomes

To generate these savings, the initiatives in place at CH2 are:

- Exposed thermal mass passive design and night purge;
- Use of smart cooling and heating – cogeneration, chilled ceiling panels and beams, and phase change materials;
- Low energy fittings – including lights;
- Use of natural light;
- Use of solar power;
- STET and flat screens.

Lessons

The main lesson in the integration of the energy efficient initiatives is the importance of design team integration. The collaborative framework from the concept stage allowed all the consultants to discuss the objectives for CH2, and to reach consensus as to the most efficient integrated design.

Systems such as thermal mass, natural ventilation and radiant cooling requires the collaboration of all involved from the concept stage in order to work efficiently.

More detail

The commercial property sector is responsible for 8.8% of Australia's greenhouse gas emissions, using about $4billion worth of energy each year. It has the fastest rate of growth of greenhouse emissions of any sector, with emissions set to almost double to 62 million tonnes of CO_2 by 2010.

In Victoria, 12% of greenhouse gas emissions come from commercial buildings and within the City of Melbourne's municipal boundaries that figure is approximately 60%. Because of this, the City of Melbourne's Zero Net Emissions by 2020 Strategy has a strong focus on achieving energy efficiency and greenhouse abatement in the built environment. CH2 plays an important role not only in reducing Council's energy use and associated greenhouse impact, but also demonstrating to the community how it can be done and the aims of Zero Net Emissions by 2020 strategy realised.

In a typical Australian commercial office building, approximately half the energy used provides 'base building services' such as air-conditioning, hot water, lifts and common area lights.

The other half is used in the tenancies- mainly lighting and office equipment. In this particular case the 'tenant' is primarily the City of Melbourne, with a small amount of retail space on the ground floor.

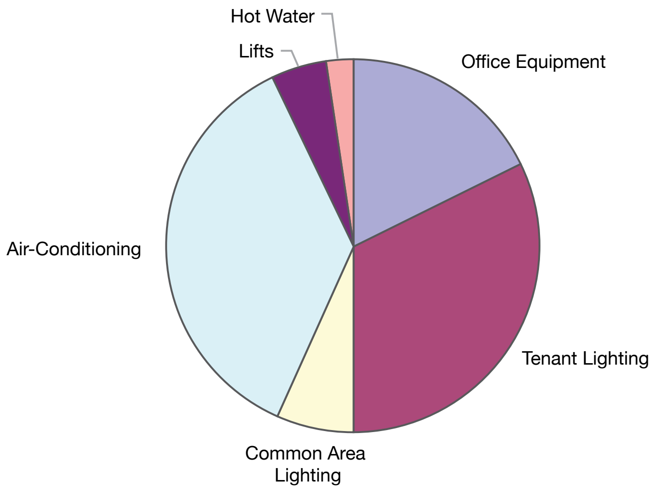

Figure 2. Typical Breakdown of commercial building energy use, AGO http://www.greenhouse.gov.au/lgmodules/wep/buildings/training/training3.html

In the case of CH2, the innovative design has focussed primarily on 'heating, ventilation and cooling', or HVAC, which is represented in the pie chart above as 'air conditioning'. HVAC is a complex array of services needed to deliver a comfortable working environment through heating, cooling and providing acceptable air quality.

After analysing Melbourne's climate, it was determined that for CH2 most of the energy for temperature control is likely to be needed for cooling the building, with a small amount of heating in the winter months.

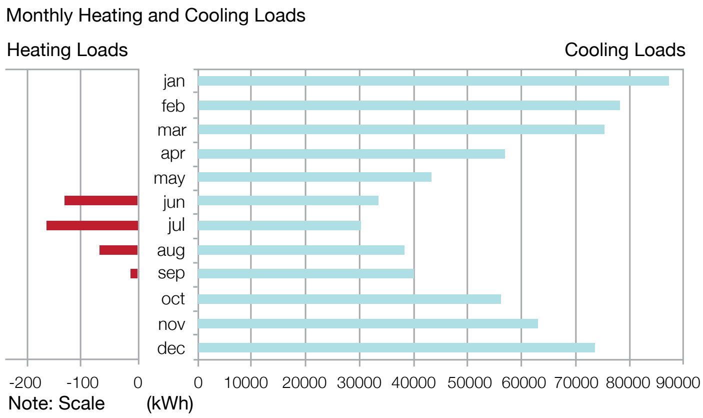

Figure 3: The heating and cooling loads estimated for the building (AEC)

The energy efficient design elements and systems that comprise the HVAC services include passive design techniques (thermal mass, night purging, ventilation stacks), as well as more active systems (displacement ventilation, chilled beams and ceiling panels, phase change material and shower towers).

Passive design techniques

Passive design is an approach that aims to achieve simple, non-mechanical design solutions to issues such as heating, cooling and lighting. It makes use of the orientation of the building, it's natural environment and weather conditions, and the characteristics of the building materials. It can produce significant savings in energy consumption, as well as savings gained in avoiding or decreasing the need for mechanical plant such as air conditioners. Some of the passive design features used in CH2 include night purging, thermal mass and ventilation stacks. Many of these are discussed in greater detail in other snap shots.
The following is a brief outline.

Thermal Mass

Thermal mass is a term given to the heat retaining qualities in the mass of a building material, and can play an important role in the energy efficiency of a building. Materials with high thermal mass, like concrete, store and release energy needed for heating and cooling more readily than materials with low thermal mass, like plasterboard. A building with high thermal mass is protected from big temperature swings and therefore will provide a higher level of thermal comfort year round. In the case of CH2, outside air from the night purge cools the 180mm-thick pre-cast concrete ceilings. The ceilings store this coolness because of their high thermal mass. In much the same way as a cement wall remains cool for a few hours in the morning after a cold night, this 'coolth' radiates back into the office space during the day and contributes to the cooling needs of the offices, thereby reducing air conditioning plant energy loads by up to 14 per cent in summer.

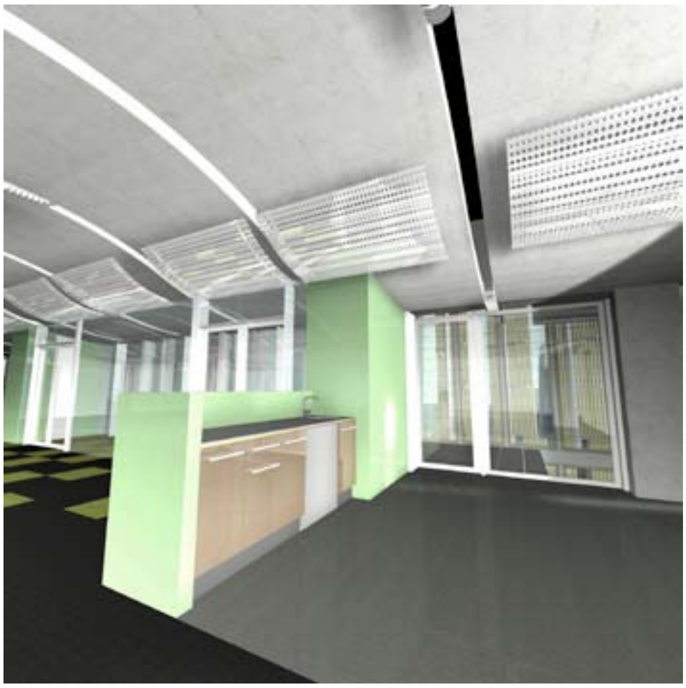

Figure 4. High thermal mass precast concrete ceiling panels (DesignInc Melb)

Night Purging

The main function of the natural ventilation is to remove the heat from the vaulted ceiling at night – this is called night purging. Windows on the north and south façades open to allow fresh cool air to enter the offices, move over the ceiling and remove built up heat (see Figure 3).

Further, the high levels of internal thermal mass in the ceiling absorb and hold the coolth. During the day, the cool internal surfaces absorb heat from any infiltrating warm air and act to lower the internal mean radiant temperature.

Sensors close the windows when they detect high winds and rain or higher external temperatures.

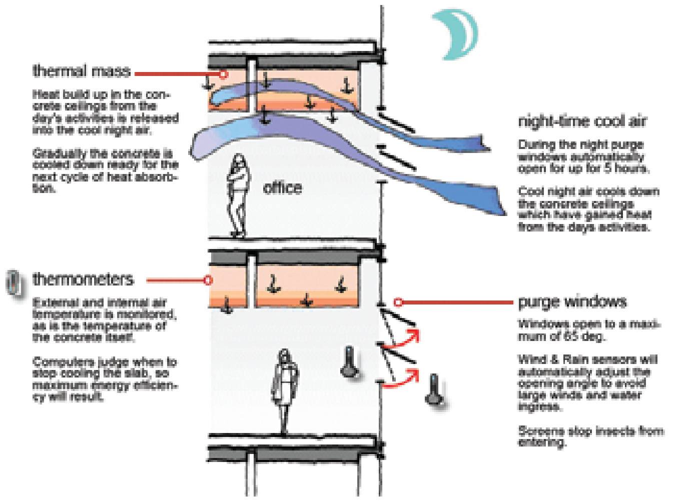

Figure 5. Demonstrating night purge and thermal mass (DesignInc Melb)

The more thermal mass exposed directly to the internal environment, the more effectively it will work as part of the night purging process. This means not obscuring walls with cupboards and panels, or ceilings with acoustic tiles or drop-panels. It also means a relatively unobstructed interior to promote air flow.

Such systems are only suitable for climates where night-time temperatures are below about 20-22°C but not too cold as to be uncomfortable. There are also the obvious issues associated with security when windows or vents are left open at night, however, these can usually be overcome.

The images shown in the preceding section demonstrates the effectiveness of the buoyancy driven night purge. There is no turbine driven exhaust assistance modelled and so the entire exhaust is driven by the stack effect of the exhaust ducts.

Figure 58 below gives a numerical representation of the night purge efficiency over the four hours modelled.

Time (hrs)	Level 2	Level 5	Level 9
0	24.0	24.0	24.0
1	20.0	20.3	20.9
2	19.7	19.8	20.3
3	19.6	19.7	20.2
4	19.6	19.7	20.1

Figure 58-CFD Temperature result summary

Figure 6. Excerpt from the AEC report on the passive design of CH_2

Ventilation stacks

Ventilation stacks are situated on the north and south facades of the building. On the north side, which receives more sunlight, the stacks are a dark colour that aids absorption of the sun heat, helping to heat up the air inside the stack which rises and is exhausted out the top. This creates a pressure differential, pulling cool fresh air through the building. The ventilation stacks are angled so that they increase in size up the building, facilitating air movement and allowing for the increased volume of air coming from the building. This has the by-product of allowing larger windows to encourage natural light to enter at street level where there is the least natural light and smaller windows at the top, where natural light is abundant. (see Figures 7 and 8)

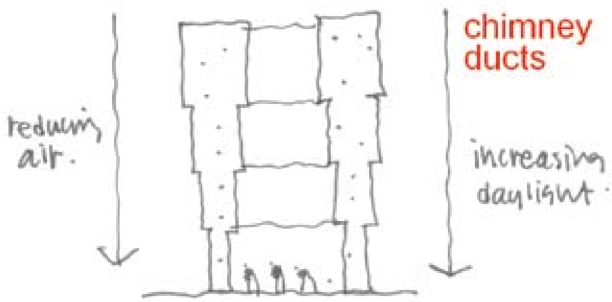

Figure 7. Image from the initial workshop of the stack and window concept

Figure 8. Southern and northern facades (DesignInc Melb)

The modelling shows that the rising exhaust ducts are an important part of the CH_2 design. During the daytime they allow a negative pressure air relief whilst the floors are under positive pressure (this is very difficult to achieve through windows directly open to the outside). At night they allow a stack to be generated as the building cools, this stack would not occur without the exhaust ducts. It is further shown that by designing the top of the shafts to create a negative pressure zone, such as with a venturi, wind effects will also enhance the flow of air up the exhaust duct. Quote from AEC report on passive design

Smart cooling and heating

These passive design elements are supported by a range of innovative HVAC approaches, which complete the design's role in heating, cooling and ventilating the building.

Displacement Ventilation

A major part of designing a ventilation system is the minimum fresh air requirement of the workspace. High levels of fresh air are known to deliver health benefits to the workers, and improve workplace productivity (see Snap Shot 14: Indoor Environment Quality). CH_2 has set its minimum fresh air requirement to 22.5 litres per second per person, significantly higher than the standard rate usually adopted at 10 litres per second per person. The USA standard is 10 litres per second per person (ASHRAE Standard 62 2001) and European standards range from 10–20 litres per second per person.

In a typical commercial office building, fresh or treated air is distributed throughout the building through a system of overhead ducts, mixing with the stale air already in the space. This system mixes the fresh and stale air, and impurities such as dust, gases and germs in the workspace are distributed throughout the floor.

The CH2 building however uses displacement ventilation. Fresh air is fed into the offices at low speed through individually controllable vents in the floor. As the air warms from heat sources (such as people, lighting and computers), it picks up impurities (becomes 'stale'), rises and moves out of the space via vents in the ceiling. This means that fresh and stale air do not mix, instead the fresh air 'displaces' the stale air.

An increasing amount of research shows that low amounts of fresh air can be directly linked to low productivity and sickness, including colds and flu. As the stale air is quickly and more effectively transported out of the workspace through displacement ventilation, impurities (such as flu germs released from a person sneezing) are less likely to spread around the workspace.

Displacement ventilation offers significant cost and operational advantages for indoor climate control, by providing controllable supply air volumes at low velocities throughout a wide variety and size of occupied zones – without creating cold air draughts.

With a traditional air ventilation system, achieving a higher fresh air level requires increase energy needed to maintain the internal environment within the set temperature range, but the IEQ benefits (see Snap Shot 14: Indoor Environment Quality) outweighed this slight increase and was-off set in part by the cogeneration system.

This is done at lower operating costs than a powered system, and greatly reduces maintenance requirements.

Figure 9. Prototype image of subfloor

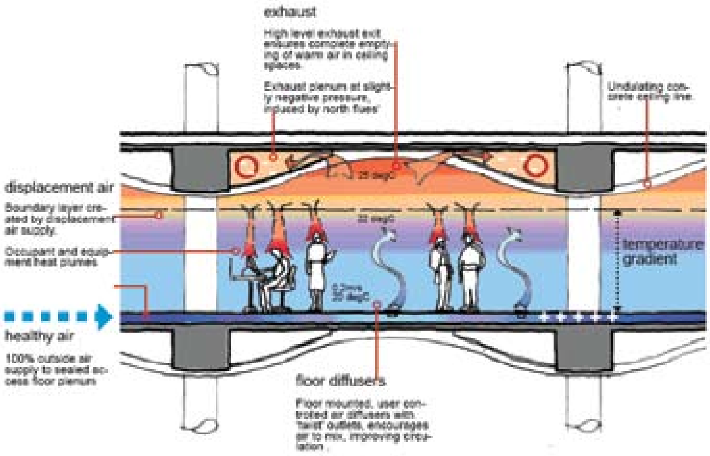

Figure 10. Natural air diffused at low rates from the subfloor (DesignInc Melb)

Chilled Beams and Ceiling Panels

Cold water is pumped through panels (situated on the ceiling), and beams (situated around the perimeter windows of the office space) on each floor, 'chilling' them. The water extracts the heat from the air, thereby cooling the air. The radiant cooling this provides has been shown to be the most comfortable way to cool an indoor environment (see Snap Shot 16: Chilled Panels and Beams).

Figure 11. Chilled ceiling panel

46% of an individual sensation of thermal comfort is from radiant heat exchange. (Szokolai quoted AEC presentation at the Charrette)

Phase Change Material

The use of Phase Change Material (PCM) is one of the most innovative aspects of the CH2 project. The PCM is used to cool the water that runs through the chilled beams and panels, and is often referred to as the 'battery' of the building. It keeps the water circulating through the chilled panels and beams at the desired temperature. This also allows the building to benefit from any cooling that can be captured and stored at night and from the water chilled by the shower towers. (See Snap Shot 15: Phase Change Material for further information)

Shower Towers

The shower towers on the southern façade help to control the indoor air temperature. Outside air is drawn in from 17 metres or more above street level and channelled into the top of the shower towers. The towers are made from tubes of light-weight fabric 1.4 metres in diameter. As the air falls within the shower tower, it is cooled by evaporation from the water. The cool air is supplied to the retail spaces in the building, and the cool water is used to assist with the phase change process by pre-cooling some of the water circulating through the chilled ceiling panels (see Snap Shot 6: Shower Towers for further information).

Figure 12. Shower tower (DesignInc Melb)

Natural light

Lower floors generally receive less daylight than upper floors. Combined with the need for the stack size of the thermal chimneys to be larger at higher levels, windows on the north and south facades are able to be larger on the lower floors than the upper ones. Further, this allows the total amount of glass to be minimised, reducing energy loss and maintaining desirable natural light levels.

In Melbourne a 50% glass to wall ratio balances natural light and heat loss or gains. Sensors monitor the amount of daylight coming in and adjust the artificial light required accordingly.

External light shelves on the north façade reflect sunlight onto ceilings and produce a soft indirect light, reducing artificial lighting requirements. Sensors increase and decrease the artificial lighting according to the amount of sunlight being reflected into the building; thus a balance of natural and artificial light is achieved.

Artificial light

CH2 has a lighting system that includes daylight and movement sensors, low energy ambient lighting and individual task lighting. The artificial lighting is made up of a custom made T5 lighting called 'glow worms', and individual task lighting. The aim is to achieve a lighting power density of less than 2.5 Watts/m^2 per 100 lux, which results in an almost uniform ambient lighting level of 150 lux. The use of T5 light fittings for ambient lighting and individual task lighting for workstations will consume 65% less energy than the lighting system in the Council's current building.

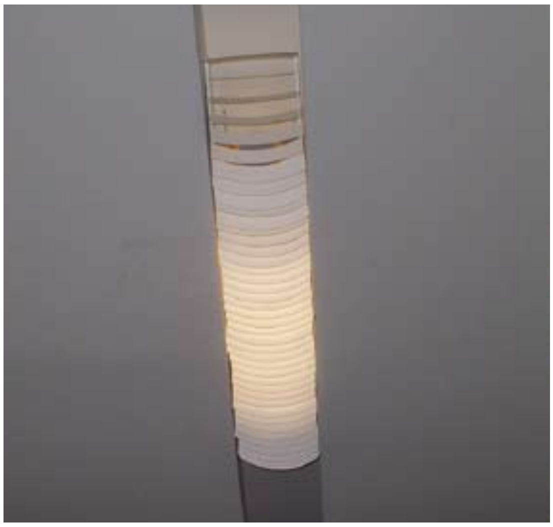

Figure 13. Glow worm light fitting

The lighting system has been designed to provide a number of separately switched zones per office floor, each no greater than 100m^2 (see Snap Shot 20: Lighting for more information).

Energy sources

Cogeneration

Another relatively simple innovation which CH2 incorporates is the use of a generator during the day. This daytime use enables the building to use both the energy and excess heat produced by the generator. The generator produces electricity from natural gas, which is less polluting than producing mains electricity by burning coal. The heat produced by this generator is used by an absorption chiller which uses heat exchange technology to cool and dry air (see Snap Shot 21: Cogeneration for more information).

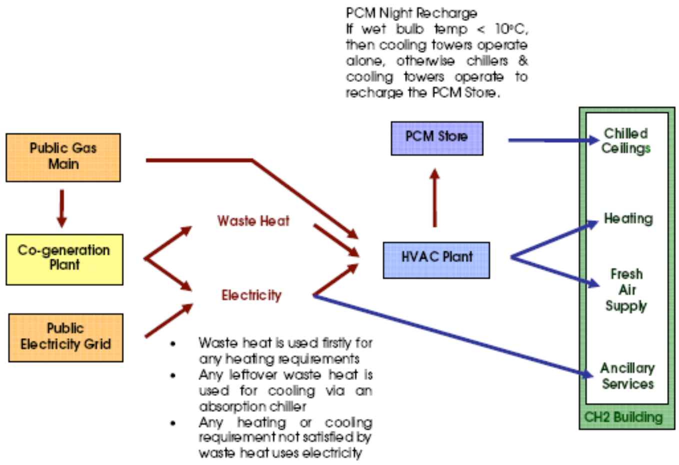

Figure 14. Summary of all the active energy systems in the building (AEC)

Solar power

Some photovoltaic panels have been integrated into the design. They are Origin Energy slither technology panels which are more efficient in production and generation than the standard crystalline panels. The area taken up by the panels is 26m^2 generating an estimated 3.5kWh peak load of electricity from sunlight, which is equivalent to the power required to operate the western shutters.

Figure 15. Model of roof garden with solar panels

Additionally, 48m^2 of solar hot water panels are being used, providing 60% of the hot water supply.

Flat screens and thin client (latter was not used)

Liquid Crystalline Display (LCD) computer monitors are expected to consume 77% less energy than older computer monitors (cathode ray tube monitors). The adoption of the LCD monitors and the thin client technology for the computing requirements will reduce the internal heat load and therefore, the amount of cooling which needs to be provided. The thin client eliminates the need for a Central Processing Unit (CPU) using 85 Watts at each desk. Combined with a LCD screen, at 30W, instead of the 80Watt CRT screen, this saves 127 watts per desk.

Figure 16. Comparable energy savings between monitor types and client (AEC)

Subsequent testing of the thin client capability uncovered some shortcomings in its application for the City of Melbourne, and this option was not adopted. Alternatives using inbuilt power reduction and efficiencies were then investigated and implemented.

Building management system (bms) – bringing it all together

The other key energy initiative is the building management system. This is an integrated, comprehensive system of management and monitoring of all the buildings systems, from water treatment to heating and cooling systems. Though this adds to the complexity of the building, it provides the opportunity to manage the building very efficiently.

The BMS consists of 2,500 measuring points throughout the building, tracking for example the temperature of the air and the concrete vaulted ceilings. It has been fine tuned over 4 seasons of CH2's first year of full operation.

Expected performance

CH2 is expected to be extremely energy efficient. Based on the Australian Greenhouse Building Rating Scheme, CH2 emissions will be 60 per cent less than a top-rating 5-star building, saving around $36/m²/yr or $270,000 per year. The expected savings are shown diagrammatically below.

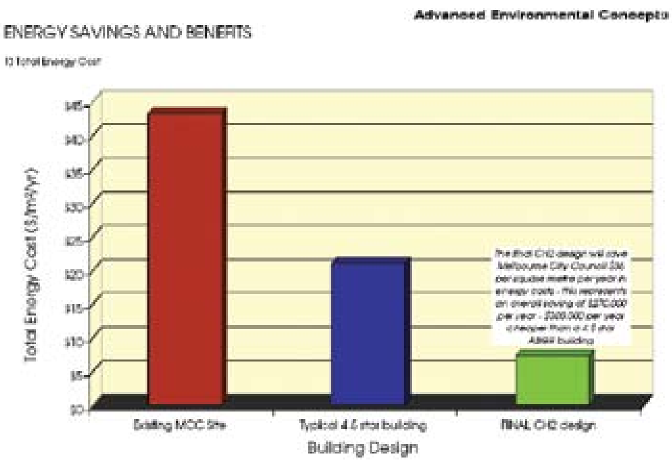

Figure 17. Expected cost performance in $/m²/yr (AEC)

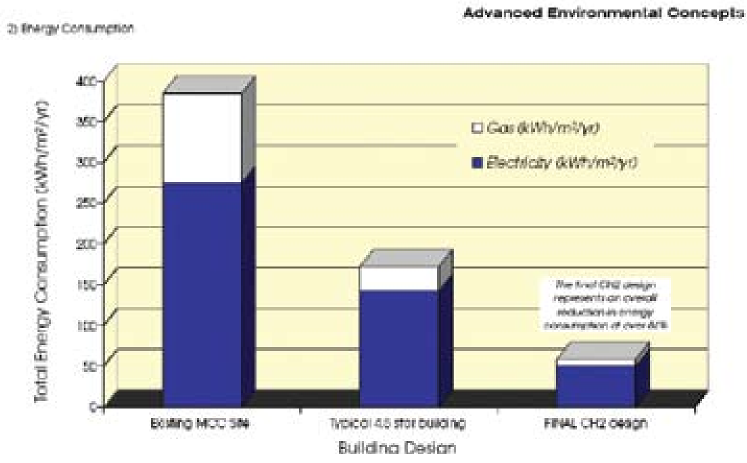

Figure 18. Expected consumption performance in kWh/m²/yr (AEC)

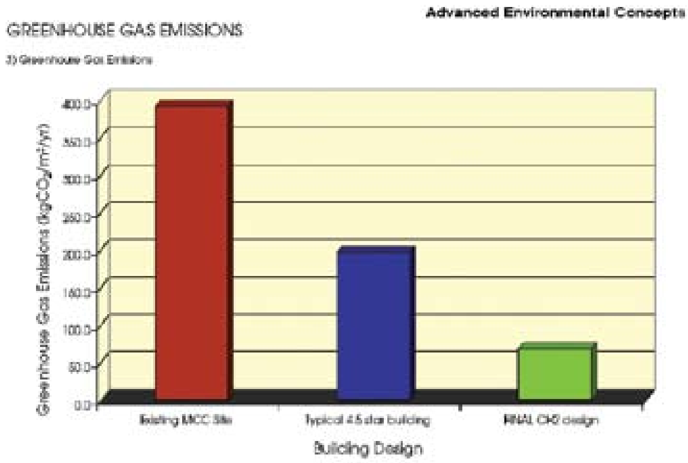

Figure 19. Expected green house gas emissions in kgCO2/m²/yr (AEC)